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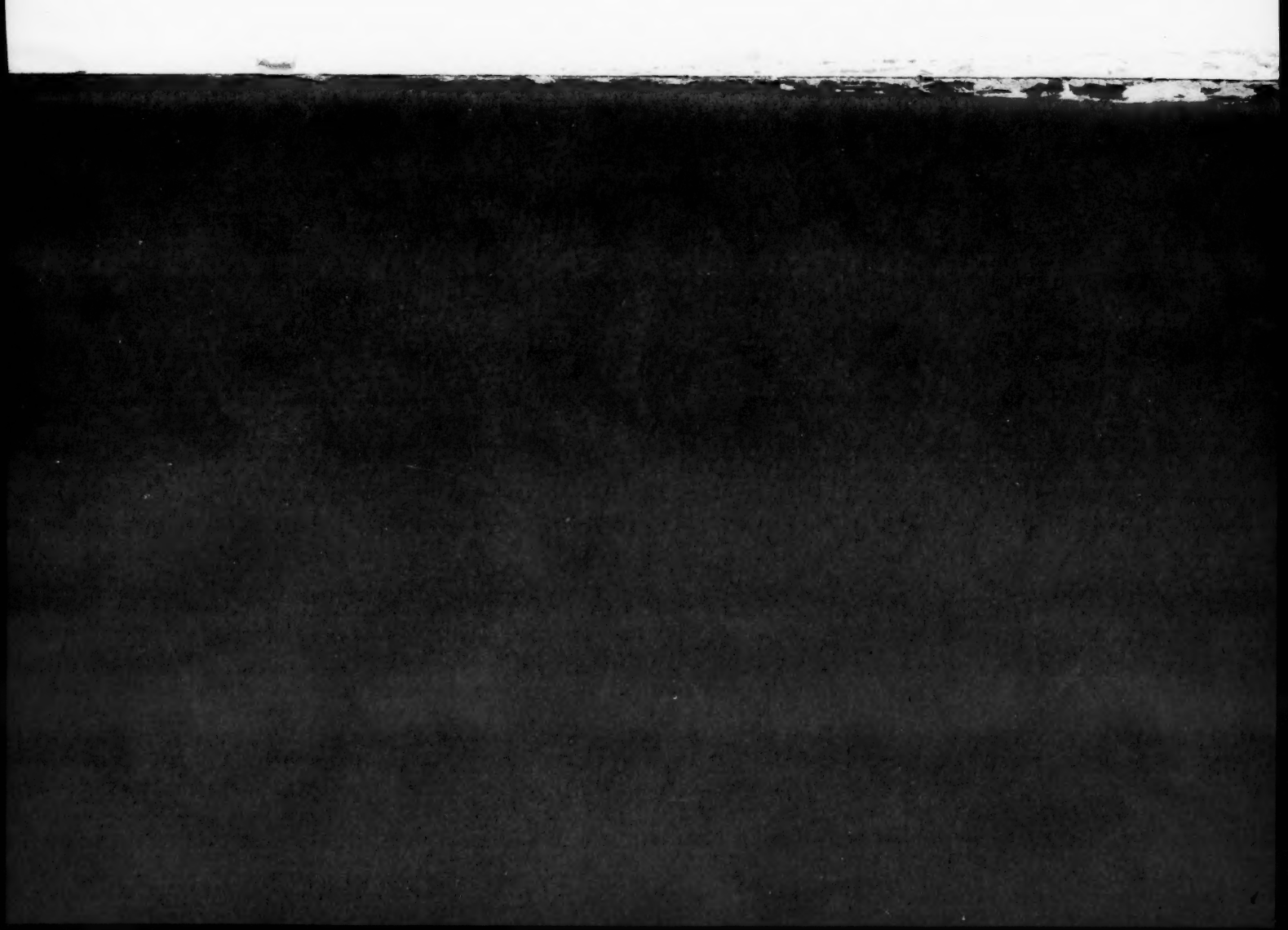

THE TWENTY-FIFTH ANNIVERSARY OF THE FOUNDING OF THE DENISON SCIENTIFIC ASSOCIATION

On the evening of April 12, 1912, a special meeting of the Denison Scientific Association was held in commemoration of its twenty-fifth anniversary, Prof. Theodore S. Johnson presiding. The following program was arranged for the occasion: "A statistical study of the contributions published in the Bulletin of the Association," Prof. Frank Carney; "Greetings from the Board of Trustees of the University, and reminiscences of C. L. Herrick," Prof. A. D. Cole; "The early years of the Association," Mr. Wallace H. Cathcart; "The Foundations of Culture," Prof. C. Judson Herrick.

In opening the exercises, President Johnson explained the purpose of the Association in the life of the college, commenting felicitously on its sustained growth and the present outlook.

Dr. Carney reviewed, by tabular classification, the contributions of the several laboratories to the sixteen volumes of the Bulletin published by the Association. When Clarence Luther Herrick, founder of the Association, established the Bulletin, but two departments of science were maintained by the University, Natural History and Physics; in a short time the former was divided into Geology and Zoology; for many years the courses in Botany and Chemistry were given by the professors of Geology and Physics respectively; a department of Botany was organized in 1904, of Chemistry in 1905; partly for these reasons there is considerable range in the number of contributions by the several laboratories.

The Board of Trustees was represented by Prof. A. D. Cole, head of the department of Physics at Ohio State University, who for several years, while professor of Physics at Denison, was an active member of the Association, and for a period acted jointly with C. L. Herrick in editing the Bulletin. Professor Cole expressed the greetings of the Trustees, and their satisfaction in, and approval of, the Association's activities. The greater part of his time was given to a narrative of incidents connected with the work of C. L. Herrick during the early period of the Associa-

tion, illustrating the remarkable energy and optimism of its founder.

Mr. Wallace H. Cathcart of Cleveland, also a member of the Board of Trustees, was a charter member of the Association, and a student of C. L. Herrick. His interesting reminiscences relating to Professor Herrick disclosed an alert and sympathetic appreciation of the work of this great teacher whose contagious enthusiasm has withstood the twenty-odd years which Mr. Cathcart has given so largely to business affairs.

The Association meets every two weeks during the college year, the program consisting of two five-minute section reports, and one paper, each from a different department. The subject matter presented is grouped under the following heads: (1) Botany, (2) Chemistry, (3) Engineering, (4) Geography and Anthropology, (5) Geology, (6) Mathematics, (7) Music, (8) Physics, (9) Zoology.

THE FOUNDATIONS OF CULTURE[1]

C. JUDSON HERRICK

In my childhood days I used to hear about Johnnie Apple-seed, a quaint old character who went about visiting village schools and seeking opportunity to talk to the children. He took his name from a habit of collecting apple seeds and dropping them into the ground as he went along, to raise fruit trees for future generations. His dry humor and homely precepts unquestionably helped many a school child on his way, and doubtless many of these children in later life tasted of the fruit from trees planted by the wayside by Johnnie Apple-seed. But he left no lasting impress upon the educational institutions of his time, and of the few trees of his planting which struggled through neglect to frowzy maturity, probably very few ever bore really good apples.

Johnnie Apple-seed's method was not very efficient, when measured by the standards of modern horticulture. The scientific culture of fruit trees and other farm products has long since passed the haphazard stage. Not only do we preserve and improve the physical value of the land by fertilizers, rotation of crops, etc., but the character of the vital stock itself is improved by prolonged systematic experimentation and by constant attention to selective breeding. Our government agencies in America are annually expending millions of dollars in experimental farming. But in some respects our educational system seems scarcely to have passed beyond the stage of haphazard planting.

The problems of education resolve themselves into two chief factors: first, the native endowments with which the child comes into the world; and second, the process of cultural modification by which these endowments are brought to the highest attainable efficiency—or briefly, nature and nurture. From the circumstance that the latter factor is obviously more directly under the teacher's control than the former, it has naturally followed that

[1] An address delivered at Granville, O., April 16, 1912, at the special exercises in celebration of the Twenty-fifth Anniversary of the founding of the Denison Scientific Association.

practical educational work has centered almost exclusively about problems of nurture. Our entire educational system apparently developed upon the assumption that the child comes to school with no educational capital at all and that it is the function of the school to add to nature's physical endowment such mental and moral superstructure as the consensus of educational wisdom has decreed is best for mankind, the individual's welfare not being taken into account, except as he is one unit in a homogeneous mass.

In higher educational work we have in some measure advanced beyond this mechanical process of squeezing all men's minds (and all women's, too) into a single preformed mold by forcing them all through the same prescribed course of study and throwing out as defective or incorrigible all who cannot be made to fit without too great pressure. But in the elementary and secondary school the stuffing and squeezing process often goes on about as mechanically as in a brickyard.

Let us look into this thing from the genetic standpoint. In the matter of origins, the poet tells us that

> Not in utter nakedness,
> But trailing clouds of glory do we come
> From God who is our home.

On the other hand, it is charged against the biologists that by their emphasis on the descent of mankind from brutes they are dragging the race down from a position "a little lower than the angels" to a stage but little higher than the monkeys.

I do not feel myself competent to present a scientific defense of all parts of Wordsworth's "Intimations of Immortality," and yet I do not think that one violates the spirit of his reflections in maintaining that a critical examination of all the data regarding the evolution of man shows very clearly that the best as well as the worst elements of human character strike their roots downward into the common biological soil. This is not to deny that through many of the blind gropings of childhood, through

> Those obstinate questionings
> Of sense and outward things,

there shines a light of heavenly origin; for

> Heaven lies about us in our infancy.

But the biologist would suggest that most of these heavenly influences have reached the child life through the medium of an indirection, like rain from above upon the biological soil from which that child life has sprung.

In short, if the doctrine of evolution has any value at all in the study of human origins (and we must conclude that it has), then it must be frankly and honestly accepted just as far as known fact demands. It must be pushed to its limit or it breaks down utterly; for its fundamental principle is the law of continuity of process in nature. The interruption of the process at any point breaks the chain and leaves in our hand only the useless fragments of discredited theories. And if evolution be one of the basal cosmic laws, as I believe it is, it is inconceivable that it should break down at the finish.

One of the saddest chapters in the history of human thought is the story of the half century of conflict between theological intolerance and scientific narrowness following the publication of Darwin's *Origin of Species*. This era is happily past and there remains now merely the task of the articulation of all knowledge from whatever sources derived, into a unitary scheme of things. Many of our ablest naturalists have been unable to see beyond the limits of their own fields of endeavor. Even Mr. Huxley, in the ripest years of his life, was inclined to draw a sharp contrast between what he called the cosmic process and the elements of social and ethical progress. He says, "The cosmos works through the lower nature of man, not for righteousness, but against it." And again, "The ethical progress of society depends, not on imitating the cosmic process, still less in running away from it, but in combating it."

Doubtless much harm has been done to sound science by ill-advised attempts to derive all higher social and ethical institutions directly from "ape and tiger methods" of evolution. But this "gladiatorial theory of existence" is not the whole of the cosmic process, as Huxley seems to imply. "The history of civilization," he says, "details the steps by which men have succeeded in building up an artificial world within the cosmos." This is a very remarkable statement to come from the greatest champion of modern evolutionary theory; for by what right does he separate human civilization from the rest of the cosmos? This civilization has grown up, not apart from the process of nature, but within it,

and failure to recognize this elementary principle has wrecked many a promising sociological and ethical enterprise.

An examination of the behavior of many lower animals (birds, for example) presents us with many instances of tender care of offspring and mates, of the delicate attentions of courtship and of heroic self-sacrifice, which cannot be distinguished objectively from altruism, parental love and other noble mental qualities of mankind. By what right do we admit the derivation of malice and avarice from brutes and deny this in the case of love and altruism? And love and altruism are as essential adaptive qualities in the elaboration of the higher social fabric of civilized human communities as are parental care and self-sacrifice for the preservation of a bird community.

And now, returning to our point of departure, let us inquire again what it is which the normal child brings with him into the world? First, there is a sound body, whose perfection of form and function is the direct product of the survival of the fittest and the elimination of weaklings during countless ages of past evolutionary history of the "ape and tiger method."

Then, there is a large collection of inborn instincts, the time and manner of whose successive appearance is predetermined by the hereditary organization of the child's nervous system. These instincts are, like the body, products of the operation of natural biological laws. It is a common idea that animal conduct is regulated by instinct, while man is controlled by reason. Nothing could be farther from the truth. How far animals are guided by reason, I am not now prepared to say; but it is certain that James is correct when he says that no animal possesses so many instincts as man himself. These instincts are often masked or supplanted early in life by acquired intelligence and so are commonly overlooked.

In the third place, the child is born with the capacity for individuality in his further mental development, an ability to profit by experience (his own and his elders'), or briefly, docility. All three of these are native endowments and, within rather wide limits, are common to all members of the race. The general bodily form and the pattern of instinctive behavior run quite true to type in all members of a given stock; but the capacity which I have termed docility is much more variable. And, aside from this congenital diversity in intellectual capacity among

the members of a given child population, still more variety is introduced into the problem by the fact that all truly intellectual attainment, as distinguished from the innate instinctive pattern, must be individually acquired, and its character will depend wholly upon the personal experience of the child himself and the nature of the environment within which this experience must be gained.

The structural basis of this three-fold inheritance is very plainly seen in (1) bodily configuration; (2) the inherited form of brain and its internal web of nerve cells and fibers, which provide a fixed mechanism, common except for minor variations to all members of the race alike, for the performance of their common instinctive actions; and (3) the large association centers of the brain, the exact form of whose internal organization is not wholly predetermined at birth, but is shaped for each individual separately during the course of his growth period by the process of education to which he is subjected.

This third element is by no means a new structure in the human brain. It has been my task for many years past to study the evolutionary history and primeval sources of these correlation centers as they are found in the lower animals. It is found that this tissue is present in all lower vertebrates and that its amount is directly proportional to the intellectual capacities and docility of the animals exhibiting it. In the nobler species of animals and in man it does not replace the lower reflex and instinctive mechanisms, but it is superposed upon these. None of these higher associational (intellectual) activities are possible, except through the mediation of the lower or instinctive centers. Neurologists, accordingly, now distinguish an old brain (palæencephalon), which is common to all members of the vertebrate branch of the animal kingdom, from a new brain (neencephalon), which is practically coextensive with the cerebral cortex. The new brain, with its functions of correlation, is really as old, so far as its first beginnings are concerned, as the old brain; but, whereas the latter attains its full development as a reflex and instinctive apparatus in the lowest mammals, the former continues to increase in size and importance and it is still increasing in the civilized human races today.

The kangaroo is one of the lowest types of mammals. A kangaroo with a body weight of about 100 pounds has a brain weigh-

ing a little less than 2.5 ounces (64 grams in Macropus rufus, see *Ziehen* in Bardeleben's *Handbuch der Anatomie*, 1903), or a ratio of brain to body weight of 1 : 711. In the human race this ratio is 1 : 42. The average brain weight of European men is about three pounds (1353 grams), the brain being 21 times as heavy as that of a kangaroo of about the same body weight. This increase in the weight of the human brain is almost entirely localized in the association centers of the cerebral cortex and structures immediately dependent upon them, the old brain remaining on practically the same level as in the kangaroo, except for the actual reduction in man of some of the simple sensory apparatuses, notably the centers for the sense of smell.

An exhaustive study of all that we know of the evolution of animal behavior (including animal intelligence) and of the evolution of the brain shows that throughout the history of animal development these two processes go hand in hand, viz., the development of increasing complexity of the reflex and instinctive life, with a parallel elaboration of the old brain, and, on the other hand, the development of higher intellectual capacity and docility, with the elaboration of the new brain, or cerebral cortex and other parts directly connected therewith. This relation, we may be sure, is no accident.

Now, our educational systems in general have recognized that the child brings into the world no *mental* endowments ready-made—no knowledge, no ideas, no morals. These have to be developed anew in each generation under the guiding hand of education, for they are the functions of those association centers whose nervous pattern is not fully laid down at birth, but must be elaborated slowly during the plastic growing years by personal experience. This lesson we have learned and learned so well that we devote one-third of the average span of life of our most promising youth to the educational training necessary to ensure the highest possible development of the latent cultural capacities of these association centers of the cerebral cortex.

But we, as educators, have too often been blind to the further fact that the child brings something with him into the world in addition to the unformed plastic materials of his association centers, viz., an immense capital of preformed and innate ability, which takes the form of physiological vigor and instinctive and impulsive actions, performed for the most part automatically

and unconsciously. This so-called lower or animal nature is ever present with us. In infancy it is dominant; childhood is a period of storm and stress, seeking an equilibrium between the stereotyped but powerful impulsive forces and the controls of the nascent intellectual and moral nature; and in mature years one's value in his social community life is measured by the resultant outcome of this great struggle in childhood and adolescence. This struggle is education.

The answer to the riddle of life, however, lies not in a successful attack upon the native innate endowments of the child, which Mr. Huxley would apparently call his inheritance from the cosmic process, directed toward their destruction and replacement by "building up an artificial world within the cosmos." No, that would be unbiological and wasteful, for our world of ideas and morals is no artificial world within the cosmos, but it is a natural growth, which is as truly a part of the cosmic process as are "ape and tiger methods" of evolution. No higher association center of the human brain can function, except upon materials of experience furnished to it through the despised lower centers of the reflex type. So also, no high intellectual, aesthetic or moral culture can be reached, save as it is built upon the foundation of innate capacities and impulses.

We are gradually learning through the kindergarten that the most economical way to lead a child into the realm of learning is not to stamp out all of his natural interests and shut him up with his face to the wall, while he learns by rote an a-b-c lesson which is neither interesting nor useful. On the contrary, we accept as given his native impulses and automatisms, his spontaneous interests and his over-production of useless movements, and we use these as the capital with which we set the youngsters up in the serious business of the acquisition of culture. But how does it happen that we make so small use of the principles here learned in the later years of the child's schooling?

Not all of the instincts with which man is by nature endowed come into function in a sucking babe or a kindergarten pupil. Childish curiosity is our strongest ally, if only we can use it wisely, throughout the whole of the educational career from infancy to the graduate school. Anger is a mighty passion in childhood. It is not wise to eradicate it altogether; rather keep it, though under curb, for there are times when real abuses arise, which

require that the man know how to hit and to hit hard. And so with the instincts of self-preservation, of fear, of sex—these all have their parts to play in the nobler works of life and are by no means to be eradicated. The ascetic ideal of mortification of the flesh as a means of grace is fundamentally wrong in principle. Our case calls for no blind, indiscriminate attack upon the world and the flesh, but rather the subjugation and discipline of these, so that we may use them effectively in our attack upon the devil.

Conflict is inherent in the cosmic process, at least in the biological realm, from beginning to end. There is the struggle for physical existence among the animals. And even in the lower ranks of life there arises also the struggle within the individual between stereotyped innate tendencies or instincts and individually acquired experience. This is clearly shown by experiments on animals as low down as the Protozoa. And out of this inner conflict or dilemma intelligence was born. With the gradual emergence of self-consciousness in this process, arises the eternal struggle with self, that conflict which leads to the bitter cry, "When I would do good evil is present with me." Conflict, then, lies at the basis of all evolution, and the factors of social and even of moral evolution can be traced downward throughout the cosmic process.

The social and ethical standards, therefore, have not arisen in opposition to the evolutionary process as seen in the brute creation, but within that process. And our immediate educational problem is the elaboration of a practicable system of public instruction which can use to the full the enormous dynamic energy in the hereditary impulsive and instinctive endowment of the child and build upon this, in the form best suited to the respective capacities of all the separate individuals, a properly ordered sequence of studies which will develop the latent capacities of each pupil and ensure a vital balance between the strong, blind impulse of the innate nature and the acquired intellectual, aesthetic and moral control.

No single curriculum can be devised which will solve this problem. The pupils enter our schools with a wide range of hereditary endowments on the instinctive plane, with great diversity in their potential capacity for learning, and from very diverse home environments, whence by far the larger part of their "social heredity" must be derived, that influence of example

and unspoken precept which is of greater educational significance than the sum total of formal schooling. This diversity in endowment, capacity and environment must be reckoned with in our educational system. Our present custom of herding together all of the children of a given age is an injustice to all of them.

It is probably true that from 5 to 10 per cent of the children in the public schools of our large cities, for one reason or another, fail to derive much benefit from the ordinary grade work, and Dr. Gould is of the opinion that about 50 per cent of city school children are below a desirable norm of health. In the New York and Boston public schools it is estimated that about 1 per cent of the total school population is sufficiently defective or subnormal to make their segregation in special classes desirable. In Boston these defectives have for a number of years been taught in special classes in which the individual needs are closely studied. The result is that the normal children are not retarded by their slowness, and, on the other hand, by skillful special training the laggards are greatly improved, instead of being lost from school altogether, as otherwise often happens. A definite series of psychological tests has been devised by which doubtful cases can be analyzed, to determine whether the mental development of the child is progressing at the normal rate as compared with his physical development. In smaller towns and villages it is not often possible to grade the children so closely; but in nearly all cases it is at least practicable to break up each of our present grades into two sections, A and B, containing respectively the better and the poorer pupils, the A section completing the assigned work of its grade and being promoted to the next grade in advance of the B section. This plan is working well in many schools.

The first and most obvious practical step in carrying out such a program is a proper medical inspection of all school children. In cities where this inspection has been given a fair trial it has from the start justified itself on economic grounds by the check placed upon the spread of contagious diseases in schools, and at the same time it has revealed some surprising conditions.

The public school teacher's greatest problems are usually the dull or incorrigible pupils who never reach full efficiency and usually drop out in the lower grades. In a very high percentage of these border-land cases actual physical defects are found whose removal restores the child to the normal at once. And where the

defect is irremediable, this should be recognized and special provision made for the child accordingly.

From 3 to 20 per cent of the children examined in the public schools are found to have defective hearing, though the defect is unrecognized in the vast majority of these cases, with the result that an otherwise normal bright child is regarded as hopelessly stupid. It is estimated that 30 per cent of the children in the New York public schools are from one to two years behind their proper classes and 95 per cent of these backward children are so principally because of defects of eye, ear, nose or throat, which could easily be detected and remedied through effective medical inspection. Such neglect is nothing short of criminal.

Opportunity for vocational training should be provided in all public schools. The State freely educates at great expense the few who expect to become physicians, lawyers, and teachers. Why should it not give similar vocational training to the many who are to become mechanics, clerks and book-keepers? The great majority of our pupils leave school at the close of the grammar grades or earlier. The following year or two is a critical time in the life of a boy. Given at least the rudimentary knowledge of a trade and an interest in it, and the victory is more than half won. During these years his earning power is small and he is apt to drift aimlessly from one petty job to another. For this period continuation part-time schools of technology should be provided and the employer should be required to allow all minors between the ages of 14 and 18 a few hours of daylight in which to attend such schools until they become proficient enough to earn a full day's wage at their chosen trades or callings.

Much progress has been made in various communities along lines similar to these, and we may look forward to a further broadening of our educational system so as to come into still more efficient and intelligent contact with the great vital interests of the community, and so, after planting our educational seed in the school, we shall ensure by suitable after-culture a more healthy crop of men and women.

In all this we take the child as he is given to us, and after a careful analysis of his endowments and capacities endeavor by skillful guidance to assist in the formation of character. We cannot create that character; we can only help the child to build it for himself. But does our educational responsibility end here?

Shall we continue to accept the hereditary endowment of the child as the gift of God, and in consequence feel ourselves absolved from any further responsibility?

The past half century has seen a very fundamental change in the human attitude toward many similar questions. Not many years ago, when pestilence stalked through the land, it was generally accepted as a divine punishment for sin and the nation was bowed down in abject humility and repentance. Today we likewise recognize the penalty for sin; but our repentance comes to expression in the form of active sanitary precautions. We drain our swamps, screen from mosquitos and flies, vaccinate our children and safeguard the purity of our milk and water supplies.

But how slow we are to learn from any experience but our own. In the smiling valley which lies before us, we persist for more than fifty years in fouling the sources of our water supply with sewage. Must we wait until we too suffer the inevitable epidemic of typhoid fever before we profit by other towns' experiences in exactly similar cases and build our sanitary sewer?

The future of our race is in God's hand; but he has entrusted to us as a community a very large part in working out our destiny, just as he has placed a large measure of responsibility for individual culture in your hand and mine. The experience of the race has shown that the advance of culture in every civilized country is accompanied by a very grave peril.

The transfer of the evolutionary process from the biological to the social plane, from the process of the elimination of the physically unfit by natural selection to the process of the preservation of all individuals under the guidance of the few members of the community who are preëminently fit to be social and moral leaders—this change in the evolutionary process opens the way for grave abuses. Those who are intellectually preëminently fit and morally unfit become a positive menace. And the whole process of socialization of racial ideals tends toward the weakening of the physical stamina of the individual. These problems have not been solved, but enough has been done to show that the solution lies within our grasp.

In France the birth rate has actually fallen below the death rate and in the other most highly cultured portions of Europe and America the trend is in the same direction. Nevertheless, since 1880 the American death rate per 1000 population has been

reduced about 25 per cent, and this reduction is sure to continue with the diffusion among the people of better sanitary and medical knowledge. But the birth rate has fallen off even more rapidly and the percentage of defectives has increased.

This is the great problem of the twentieth century—eugenics. It is by no means insoluble and we already have the data necessary to make great progress. Our knowledge of human heredity is well advanced. We know, for instance, that certain defects, like congenital deaf-mutism, will reappear in every generation as a family trait when two deaf mutes marry; but, on the other hand, this defect can be bred out of a family by suitable crosses with family lines in which it is unknown. The extreme forms of degeneracy, like feeble-mindedness, are distinctly hereditary. In one case on record, in a single family of 319 members many died in infancy, and of the surviving children 119 are feeble-minded and only 42 are sufficiently near to normal to be able to care for themselves. In such cases, all of the children should be kept under surveillance and prevented (by committal to institutions, if necessary) from the inevitable propagation of their defects which results from intermarriage with their own kind.

Dean Sumner, of the Protestant Episcopal Cathedral of Chicago, has recently announced that he will in the future solemnize no marriages save in cases where both parties bring a certificate from a reputable physician of freedom from certain physical and mental taints. This marks one of the greatest advance movements of our time, and the day should speedily come when the matter of the granting of marriage licenses will be placed by the State in the hands of an expert medical board. Today we examine and license all applicants who wish to run an automobile or a pedlar's wagon, but make the assumption of the responsibilities of matrimony a subject for flippancy and jest.

These are simply illustrations of practical movements which can be begun at once, to ensure the improvement of our hereditary racial stock. The whole matter of "National Vitality, its Wastes and Conservation," is discussed in a comprehensive way in the Bulletin of the Committee of 100, published by the Government Printing Office at Washington in 1909.

President Taft, on the 9th of this month, signed a bill creating a Children's Bureau in the National Department of Commerce and Labor, which is destined to play a large part in the future

protection of the child in this country. There is at the present time a bill pending in the National Congress, creating a Department of Public Health, the Owen Bill, which has the support of the leaders of medical, philanthropic and social progress. It should be passed at once. As an illustration of the practical import of such legislation, it may be mentioned that our present pension roll of over $150,000,000 per annum is three-fourths of it due to illness and death from diseases that were preventable. We are building the Panama Canal under the direction of our War Department economically and well because we first controlled the sanitation of the Isthmus. All are agreed that without such sanitary control the task would be as impossible for us as it was for DeLesseps.

The hope of the future conservation of our national vitality lies in the presence in every community of centers of liberal learning and research like this college and this Scientific Association, where the scientific foundations of future success in this great movement are laid, and intelligently trained exponents of these principles are scattered throughout the community to give practical demonstration of the true course of right living.

But this movement for the conservation of national vitality is not something which we can leave to government, philanthropic, educational and other public agencies. Each one of us has his part to play, a part which is vital to our present and future national life.

The greatest single factor which is now operative to lower vital efficiency in such a cultured community as this is the artificial strain of high pressure living, which is now all but universal in all urban communities. This pressure arises, not as in former times from the struggle for bread, for mere subsistence, among the very poor. On the contrary, its most acute form is seen among the rich and the well-to-do. The struggle for wealth, for recognition and for social position has replaced with us the struggle for existence. This strain is felt not only by the men of big business and large professional responsibilities, but also by their wives and daughters, whom we are apt to think of as coddled in the lap of luxury. Our very play has come to be a most exhausting kind of work.

There are few cultured families in America where the blighting influence of business, professional or social excess is not evident.

It saps the foundations of personal health, of happiness and of family life. In its train follow neurasthenia, insanity, sterility. The health, the sanity and the enduring life of the individual and of the nation depend upon an immediate and thoroughgoing reform in these respects.

In conclusion, I wish to repeat that our highest intellectual, aesthetic and moral culture springs directly from the same vital stream as our sanity of body and mind; and He who announced that He came into this world that we might have life and have it more abundantly devoted no small share of His labors to repairs upon the biological foundation which is so necessary a basis for the elaboration of the higher life.

DRAINAGE CHANGES IN THE MOOT'S RUN AREA, LICKING COUNTY, OHIO[1]

HARMON A. NIXON AND DEXTER J. TIGHT

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INTRODUCTION

Evolution of glacial theories, as applied to Ohio's drainage systems. One of the problems that early attracted the attention of our first State Geologist, Prof. J. S. Newberry, and his assistants, after the organization of the permanent Geological Survey of Ohio in 1869, was the problem of establishing the relationship which existed between our present drainage systems and the drainage of Ohio before the glaciers of the Pleistocene period advanced into the area and deposited their load of drift. After a little more than three years of investigation, they published, along with other results, their tentative solution of this problem. From a study of Professor Newberry's work[2] in the Cuyahoga River Valley and its vicinity, and of E. B. Andrews' investigation[3] in the southeastern part of the state, we find that they are

[1] This paper is a report on investigation carried on under the direction of Professor Carney, of Denison University, to fulfill requirements in Courses 9 and 10 of the Geological Department.

[2] *Geological Survey of Ohio*, vol. ii, 1874, p. 444.

[3] *Ibid.*, vol. iii, 1878, Report on Richland, Knox and Licking Counties, pp. 310-361.

agreed that so far as these areas are involved, the gross features of the topography are the same today as before the glacial invasion. Not more than a year later M. C. Read[3] suggests the theory, based upon his work in Richland, Knox and Licking Counties, that the drainage lines of Central Ohio have taken their present alignment chiefly through glacial influence. This theory of the dual origin and difference in age of the streams of the central portion of the state, as compared with those of the other divisions, has been supported by leading geologists up to the last decade. The work of Professors Tight[4] and Bownocker,[5] of J. H. Todd[5] and Gerard Fowke,[5] has tended to substantiate Read's theory as it applies to Southern Ohio, and the work of Tight,[6] and Leverett,[7] in its relation to Central Ohio.

General discussion of drainage changes. However, within the last decade, investigations in the central part of the state, carried on for the most part under the Department of Geology of Denison University, have tended to show that a large portion of this area has derived its drainage features from preglacial influences. This theory of the age and origin of the streams of the central portion of the state seems to be more in harmony with the supposed origin of those of the southern, eastern and northern parts of the state than the hypothesis formerly so widely accepted.

Scheffel concludes in his paper, "Drainage Changes near Granville, Ohio,"[8] that the stream reversals in that section, so commonly attributed to glacial intervention, antedate the invasion of the Pleistocene glaciers and are probably due to diastrophic movements. Mather[9] has concluded from a study of the lacustrine deposits and terraces at Claylick and its vicinity that the cutting of the Licking Narrows and the consequent capture of the west-flowing Newark River by the present Licking River is not due to a stoppage of drainage, ascribed by Tight[10] and Leverett[11] to the advance into the area of the Illinoian ice sheet, but

[4] *U. S. Geological Survey,* Professional Paper No. 13, 1903, p. 108.

[5] *Ohio State Academy of Science,* Special Paper No. 3, 1900, Bownocker, Todd and Fowke.

[6] *Bull. Sci. Lab., Denison Univ.,* vol. vii, pt. ii, 1894, p. 49.

[7] *U. S. Geological Survey,* Monograph xli, 1902, p. 196.

[8] *Bull. Sci. Lab., Denison Univ.,* vol. xiv, 1909, pp. 157–174.

[9] *Ibid.,* pp. 175–187.

[10] *Loc. cit.,* p. 49.

[11] *U. S. Geological Survey,* Monograph xli, 1902, p. 155.

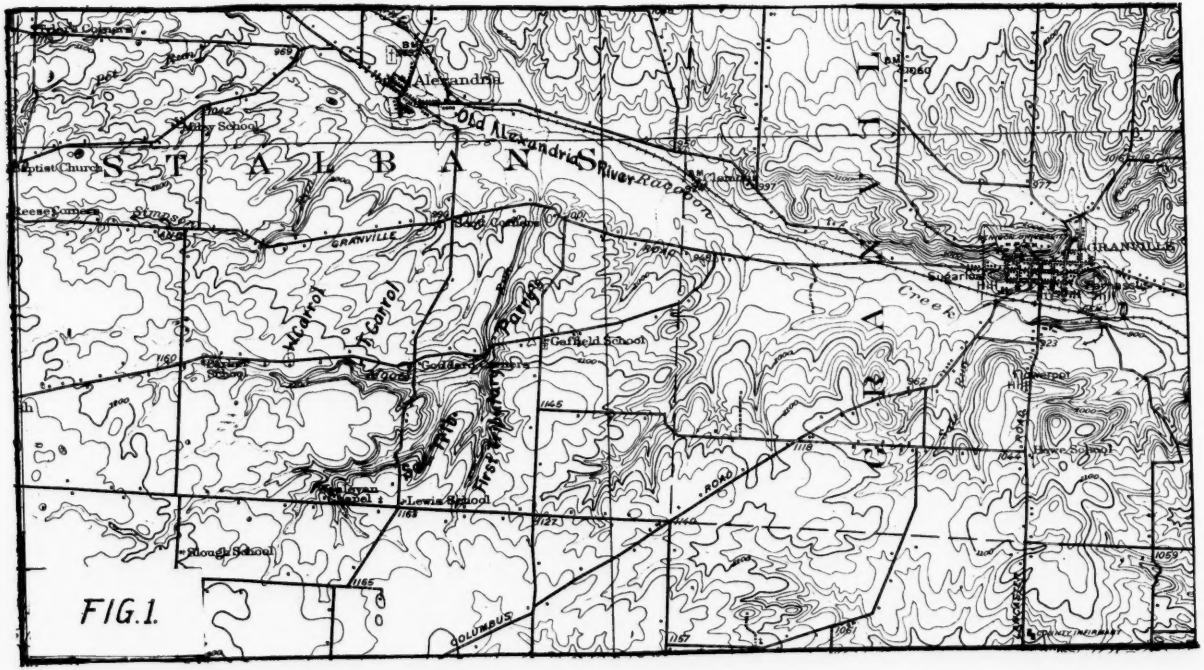
Alexandria
Old Alexandria
River Road
Granville
Boat
Creek
Garfield School
Lewis School
Rough School
Columbus
Road
St. Albans

FIG. 1.

is due to a differential tilting during the late Cretaceous, or Pliocene period, which was characterized by such movements. This can safely be correlated with the movement to which Scheffel refers, we think, because they were both locally confined, the tilts were in the same direction, and both took place at about the same time.

As a result of these and similar investigations in the state, there is a tendency among students to take the view that glaciation has not been the important factor in the diversion of streams and alteration of drainage systems which it was considered a few years ago. However, in all probability, the change of drainage which we describe in the present paper was due primarily to glaciation.

Drainage Changes in the Moot's Run Area

Detailed description of Moot's Run and its tributaries. The problem which forms the subject of this discussion is connected with the upper course of Moot's Run. This stream lies in St. Albans Township, flowing, throughout most of its course, parallel to the Raccoon and in the same direction. This portion of the stream is about two miles directly south of Alexandria. At Parry's, a half mile west of the Gaffield School,[12] the stream turns directly north, and thence flows in a fairly straight course to the Raccoon.

Certain phenomena noted in the course of this stream suggest that it is not such a one as would be developed in an age of normal erosion. These phenomena are:

1. Just south and west of Parry's a valley three-eighths of a mile in width suddenly narrows to a rock gorge 240 feet in width, a condition not found in normal erosion in a region of homogeneous rock texture and structure.

2. A repetition of the above phenomenon at the source of the second tributary of Moot's Run.

3. The axes of Moot's Run and the main portion of the second tributary are parallel to the axis of the drainage divide on the south; thus Moot's Run and its second tributary flow parallel to the divide instead of away from it.

[12] All of these points may be located at once by referring to the accompanying topographic map.

Discussion of drainage factors, as applied to this area. Scheffel has well explained in his paper, "Significance of Drainage Changes near Granville, Ohio," that there are three important factors which may interfere with or influence the normal development of a drainage system: piracy, diastrophism, and glaciation.

That glaciation has been the chief factor in the development of the Moot's Run area is proved, we believe, by evidence of both a positive and negative nature. That there have been reversals of drainage, even a superficial examination will show. Let us consider in their order the influence of these three factors on the drainage development of the area. In the paper referred to above, Scheffel roughly groups the various forms of piracy under three heads: those due to topography, to stratigraphy, and to rainfall.

Inadequacy of piracy, to account for these changes. The first is the form that is found under normal erosion. By the cutting back of its own headwaters one stream captures the headwaters of another, thus diverting a greater or less portion of its drainage system. That such has taken place in this region is inconceivable. There is no evidence of a contest between rival streams for supremacy in this drainage area. There is no well defined divide, which is usually present in such an area, and, what is more to the point, the streams which now occupy this area could not have accomplished the excavation of the present gorges, a task which the theory of piracy would assign to them. Since this is the case, we need not dwell on the other causes of piracy, a differentiation in the structure and tilt of the rocks, or a differentiation in the distribution of rainfall over the area, neither of which has been operative in this section of Ohio.

Inadequacy of diastrophism, to accomplish these changes. Since diastrophism has been so strongly urged as the chief influence in the drainage diversions of an adjoining region, its operation in the Moot's Run area might be anticipated.

Imagine a mature drainage system, with a medium-sized stream occupying its basin, into which several low gradient tributaries flow; this fairly represents the old Alexandria River and its tributaries. Now imagine a gradual tilting of the land along a north and south axis in the neighborhood of Alexandria, a mild rise but sufficiently rapid to prevent the stream from maintaining its direction by degrading its bed. What change in drain-

age would result in such a case? This question Scheffel has answered in the paper referred to above. By a differential movement of the rock a new divide was formed east of Alexandria. This resulted in a reversal of drainage, and we have the anomalous condition of a stream, with a wide mature valley at its headwaters, flowing eastward through a narrow, constricted channel at Granville.

One might immediately infer that this is the exact condition which we have in Moot's Run area. Is the reversal of drainage not due to the same diastrophic cause? We would give a negative answer, for several reasons:

1. If Moot's Run had been a normal tributary to the old Alexandria River, joining it in the vicinity of Alexandria, and this tilt had taken place, it would not have been sufficient to cause Moot's Run to adopt a course parallel to the Raccoon, and with the same direction of flow.

2. There are, however, very substantial reasons why this diversion of Moot's Run cannot be correlated with the diastrophic movement that produced the narrow section of the Raccoon Valley at Granville. An examination of the well records at the houses along the road just to the north and parallel to Moot's Run shows a slope of the rock floor to the west for over a mile. These records are as follows: At the temporary bench mark, one-half mile south of the Gaffield School, the bed rock surface is 1125 feet above sea level; at T. Carrol's[13] it is 1065 feet above sea level; at W. Carrol's its altitude is 1075 feet. It is evident, from a comparison of these heights above sea level, that the rock surface slopes slightly to the west, and has done so ever since pre-Pleistocene times. Hence the diastrophic movement to which Scheffel refers was not sufficient to divert Moot's Run into its present channel.

3. A proof, sufficient in itself to controvert the theory of diastrophism as applied to this area, is the fact that Moot's Run at the present time cuts across thick beds of glacial drift *in situ*, showing clearly that this stream has adopted its present course since the glacial period, or, at the earliest, at some late interglacial time. Since the diastrophic movement referred to took place before Pleistocene times, probably during the late Cretaceous or Pliocene

[13] For location of wells see accompanying topographic map.

period, the fact above mentioned disproves the theory that diastrophism caused the diversion of this stream. In further proof of the theory that Moot's Run has taken its present course since glacial times, is the fact that in none of the rock gorges in question do we find any glacial drift *in situ*, either in the bed of the stream or on the side of the valley, a condition which would not be likely to exist if the glacier had moved over this area since the gorges were formed. We find glacial drift on the top of these walls, but none within them.

Since we have seen that neither the diastrophic theory nor that of piracy will account for the drainage diversions in Moot's Run, we must turn to the only remaining alternative, the glacial theory.

Glaciation as an adequate cause. The glacial theory seems to account for the reversal in a very satisfactory manner. Before taking up the relation of the glaciers to the topography of this area, we will give a more detailed description of the region.

If one should start to ascend Moot's Run from its confluence with the Raccoon, he would find that for the first mile it is superimposed upon a mantle of glacial drift, which gas wells show to be about 200 feet thick. At the end of this mile, where is found the iron bridge on the Granville Road three-fourths of a mile east of Scott's Corners, the valley on both sides of the stream bed takes on a different appearance. About 75 yards to the south of the Granville Road the first outcrop of rock appears on the east bank of Moot's Run. The west bank for a long distance is a heavy band of drift, a portion of a recessional moraine that sweeps away to the north; the significance of this ice-halt, in the present problem, will be made apparent later. The rock on the east bank also soon gives place to drift, which forms the east bank of the stream for over half a mile southward. The drift on the west bank continues to Parry's, with the exception of two thin outcrops of rock, which are merely an extension of the rock slope from the opposite side rather than a distinct rock wall.

From beneath the drift at Parry's there emerges a sloping rock wall of rather steep gradient. On the east bank the rock appears a little farther down stream than it does on the west; from this point to the bend, 100 yards south of Parry's and for another 100 yards to the west of the bend, the stream is confined by a rock channel. Here the south rock wall ends, and, together with the

drift on its slopes, forms a commodious amphitheater, which is somewhat dissected by a large tributary, which joins Moot's Run, from the southwest. The rock on the north bank of the stream drops almost to the water's edge, giving place to drift *in situ*, with a very distinct contact. This drift wall flares to the north, its surface rising gradually in the same direction, but not reaching a level as high as that of the stream wall on the south.

The first tributary, south of Parry's, enters Moot's Run by cutting across a portion of the rock wall on the south side of the stream. For over 50 yards up this tributary rock walls confine it; at the upper end, these walls are about 160 feet apart. The wall on the west side is much lower than that on the east, making the tributary appear to enter Moot's Run on the side rather than at the axis of the valley; this lower rock wall, heavily overlaid with drift, blends into the drift deposits, rising to the south, which form the south side of Moot's Run Valley.

As one proceeds up this stream, which has many small tributaries, he finds glacial drift *in situ;* how thick this drift is we cannot say, in the absence of well records, but as there is drift in the bed of the stream at levels lower than the rock at the "bend" in Moot's Run, a preglacial valley is strongly suggested. The direction of flow of this preglacial stream was probably to the northwest, joining the Raccoon Valley; this inference is based on the following facts: The rock outcrop mentioned above, in the first tributary, the shoulder of rock in the opposite bank a little farther down stream, and the last outcrop in the north bank of Moot's Run, about 100 yards west of the "bend," where rock gives place to glacial drift, are in line; these outcrops probably represent portions of the northeast valley wall of this northwest flowing stream. The valley of Moot's Run, west of the last outcrop of rock, is cut for some distance in glacial drift, showing that here it crosses a buried valley.

The second tributary, near its junction with Moot's Run, has a north-south course for about one-fourth of a mile; at the point where it bears to the west "blue clay"[14] appears, showing that the old channel, just referred to, bends slightly to the west before turning northward to the Raccoon Valley. Proceeding upstream

[14] *Journal of Geol.*, vol. xvii, 1909, pp. 473–487. "Metamorphism of Glacial Deposits," F. Carney.

along the second tributary, we find that it cuts directly across the southwest wall of the preglacial valley, exposing rock almost to the top of the channel. Rock walls, for the most part, confine this tributary throughout its course to a point a short distance west of the highway north of the Lewis School, then suddenly give place on both sides to glacial drift. Here we have a repetition of the same phenomenon observed at Moot's Run, i.e., a narrow rock gorge succeeding a wide valley confined between walls of glacial drift. This stream in its westward portion lies on the "blue clay," which may represent an older ice invasion than the yellow drift composing the terraces above. This relationship suggests another buried channel.

Returning to Moot's Run, and tracing its course westward from the point where the rock bed gives place to drift, a short distance west of the "bend," we find that both walls are composed chiefly of drift for almost all the way; the valley walls are fairly high, and have the gentle slope which drift always takes. There is an occasional outcrop of rock in the bed of the stream, one in particular being noted near the house of T. Carroll, where the rock is at least 50 feet higher than at Parker's. This is probably due to the fact that the last records are from wells sunk into the descending rock slope of the old channel, which cut tangentially across the headwaters of the second tributary a little to the southeast of this point.

Résumé of glacial movements over the area. The first glacial invasion of this region, according to present knowledge, was the Illinoian, which probably reached as far south as Cincinnati, Ohio. At its farthest extent the ice front lay across Licking County in a northeast and southwest direction; we infer this from the fact that the southeast portion of the county is driftless. A very large portion of Licking County is the modified topography of a terminal moraine. The Illinoian drift is probably represented by the old "blue clay," a metamorphosed glacial deposit,[15] and the Wisconsin is represented by the so-called "yellow clay."

These ice sheets, making their final stand, deposited very heavy blankets of drift, which masked the minor drainage lines of this area. Observations on the thickness of this drift in the Alexandrian area are given by Scheffel in the paper cited above. It is probable that in our area the heavy drift deposits of the ter-

[15] Carney, *loc cit.*

minal moraines obliterated nearly all the minor drainage channels, leaving little besides the very general divide lines.

In the retreat of these ice sheets, the ice departed from the low areas last. Thus we have at each retreat of the Illinoian and Wisconsin sheets a large lobe of ice protruding down the Scioto Valley. From this lobe there extended eastward a tongue of ice which followed very closely the topography of the Raccoon Valley.[16]

Influence of glacial invasion on subsequent drainage of area. We can now see the influence that this tongue of ice exerted in shaping the drainage features which form the present topography of the Moot's Run area. The topographic map (Granville quadrangle) shows that Moot's Run lies on the side of the slope of its divide and not at the base of it; this divide, which is roughly parallel to Moot's Run, has a northwest-southeast direction. At one time it probably formed the rock wall of the old Raccoon. The outcrops of rock in the Moot's Run gorge represent the northern limit of this rock slope. From a study of the outcrops along Moot's Run and its tributaries, we have outlined the most likely extension of this wall through the area.

What would be the effect on drainage lines, if a tongue of ice from the Scioto lobe halted for some time against this divide? That such a halt did take place, we are convinced from a study of the extensive moraine deposits on the west side of the Moot's Run gorge. We also infer that in this area the tongue of ice conformed very closely to the topography of the region. Mather[17] and Scheffel[18] speak of a similar conformity in the adjoining areas. When the ice stood in the Moot's Run area, in the position above described, the axis of the divide inclining toward the ice, the drainage which flowed normally from this incline toward the Raccoon Valley would be blocked, and as a result would have to take a course along the ice front. This volume of water, augmented by the enormous amount supplied by the melting ice, and employing as tools the drift from the ice, would easily cut through the rock walls, which are of a very soft texture, mostly shale. The places where it cut across the foothills of the old

[16] Scheffel, "The Origin of Spring Valley Gorge," *Bull. Sci. Lab., Denison Univ.*, vol. xiii, 1907, pp. 154–166.

[17] Mather, *Bull. Sci. Lab., Denison Univ.*, vol. xiv, 1909, p. 176.

[18] Scheffel, *loc. cit.*, p. 164.

divide are now the rock gorges in the second tributary and in Moot's Run.

The peculiar phenomenon that we observed in the amphitheater where the second tributary joins Moot's Run is explained as follows: The collar of drift which now extends across the east side of the amphitheater is the remains of a much heavier recessional moraine, representing the position of the ice and the course of the second tributary when it made its first cut through the rock divide. But, as the ice began to retreat, the first and second tributaries took different courses, the first tributary keeping to the old course and the second tributary cutting in on the near side of the rock, keeping always against the ice front.

What is known as Moot's Run on the map did not exist when the gorges were cut. This stream has been formed for the most part since the glacier left the region. The glacier may, however, have given it the initial impulse, by a short halt of the ice where the road is now, as there is good evidence of a recessional moraine along the Granville Road, bearing to the north of Scott's Corners. It is safe to infer that this part of the stream has been cut by normal erosion in fairly recent times. If this were not the case, there would not be so many steep cliffs, which characterize young streams. This can easily be explained through the agency of normal erosion, as the second tributary into which this stream flowed was reduced to such a comparatively low gradient by the heavy ice marginal drainage.

There remains one point for which we need to account: the fact that at the bridge spanning the second tributary north of the Lewis School, the north bank is composed entirely of drift. The most plausible interpretation for this is the supposition that the ice front formed the north wall of the stream until it had cut down far enough to retain its present channel after the ice had receded from the area.

We believe we have shown that neither diastrophism, taking the form of a limited differential tilt, nor piracy, can possibly be considered as even a partial explanation of the drainage diversion in this area. In view of the fact that the only remaining alternative, glaciation, does account in a thoroughly consistent manner for all the peculiar relations that we have noted, the conclusions of the following summary appear justified.

Summary

1. Piracy is not competent to account for these changes, because the present stream drainage is not sufficient to have cut the gorges found in the area, and because the streams are superimposed upon glacial drift for a large part of their courses.

2. Diastrophism is not competent to account for these changes, because at the present time the rock floor dips to the west, precluding the possibility of a differential tilt diverting to the east the normal drainage of the area.

3. These drainage reversals are of Pleistocene age, because of the fact that the supposed diastrophic movement took place in the late Cretaceous or Pliocene period.

4. The distribution of moraine shows that a tongue of ice halted in the Moot's Run area and diverted the drainage, causing it to take a course along the ice margin. This drainage cut the second tributary and Moot's Run below their junction at the rock gorge.

5. Evidence also shows that the so-called Moot's Run in its upper course was nothing more than a tributary to its second main auxiliary, but has cut through a less resistant material, glacial drift, and has eroded its bed much faster, thus becoming the main stream.

6. The present drainage of the Moot's Run area has been superimposed upon a heavy recessional moraine, largely independent of preglacial drainage lines.

SOME PRO-GLACIAL LAKE SHORELINES OF THE BELLEVUE QUADRANGLE, OHIO[1]

FRANK CARNEY

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INTRODUCTION

Observations and studies of others. The area comprised in the Bellevue quadrangle includes portions of Sandusky, Erie, and Huron Counties. N. H. Winchell, in his *Report on the Geology of Sandusky County*,[2] merely refers to "the Lacustrine sand," which caps the limestone ridges, as "the only observable changes of level." In the *Report on the Geology of Erie County and the Islands*, J. S. Newberry only mentions "the lake ridges which traverse the county from east to west" as among "the most interesting features in the surface geology of Erie County."[3] *Report on the Geology of Huron County*, by M. C. Read,[4] contains several interesting allusions to the work done by the ice-front lakes. He noted "the old water plains, diversified by sand dunes and remains of old lake beaches;" he noted that the sand hills and associated ridges have the same elevation above lake level; that "the irregular, winding outline" of the ridges and the bordering dunes resemble the results being produced today by waves;

[1] Published with the permission of the Ohio Geological Survey, the author assuming responsibility for the observations and conclusions stated.

[2] *Geological Survey of Ohio*, vol. I, p. 594, 1873.

[3] *Ibid.*, vol. II, p. 183, 1874.

[4] *Ibid.*, vol. III, pp. 290–309.

that there is a difference in height of the north and south slopes of the ridges; and he also observed, near the county line (this is northeast of Strongs Ridge) "a low rock bluff," associated with a sand ridge, which he interpreted as the shore of a lake.

But the first, and only detailed study of any shorelines of the Bellevue quadrangle, so far as the writer is aware, is that of Mr. Frank Leverett, whose "Map of Beaches near Sandusky, Ohio,"[5] includes the eastern half of the Bellevue sheet and a large part of the Sandusky sheet which is next east. These quadrangles were not issued when Mr. Leverett did his work, and he had to depend chiefly on railroad levels for his altitudes. His map shows the Maumee, Belmore (Whittlesey), and Forest (Warren) beaches, two islands of the Warren stage, and a "Maumee bar" on one of these islands, i.e., on Sand Hill; the text refers also to one more island, about three miles directly north of Bellevue on the Sandusky-Erie County line. The small scale of Mr. Leverett's map precludes much detail. In only one particular of much importance is later investigation at variance with this map: Northwest of North Monroeville the Belmore beach crosses the county line, and is represented as turning south and west, again crossing the county line, and terminating about three miles northeast of Bellevue. On Fig. 1, of the present paper, it is noted that a spit of the Lower Maumee, northeast of Strongs Ridge, ends very near the Whittlesey (Belmore) beach; viewed from the highway, this spit might easily be taken as a continuation of the Belmore beach.

Surface features of the quadrangle. This area is underlain by rocks of the Upper Silurian and Middle Devonian; the former are basal to the more even-surfaced northwest part of the quadrangle. The plain of Lake Warren bears many slight streams draining into Sandusky Bay. Considering the sheet as a whole, there is a conspicuous absence of streams, even when allowance is made for the general flatness of the area; this is accounted for by the fact that the higher parts have underground drainage through the cavernous limestone. Sink holes are numerous in the central portion of the quadrangle from Bellevue to Castalia. The sub-surface water courses are used, unwisely, for sewage

[5] *Monograph XLI*, U. S. Geol. Survey, plate XXII, 1902, pp. 730–731, 752, 763.

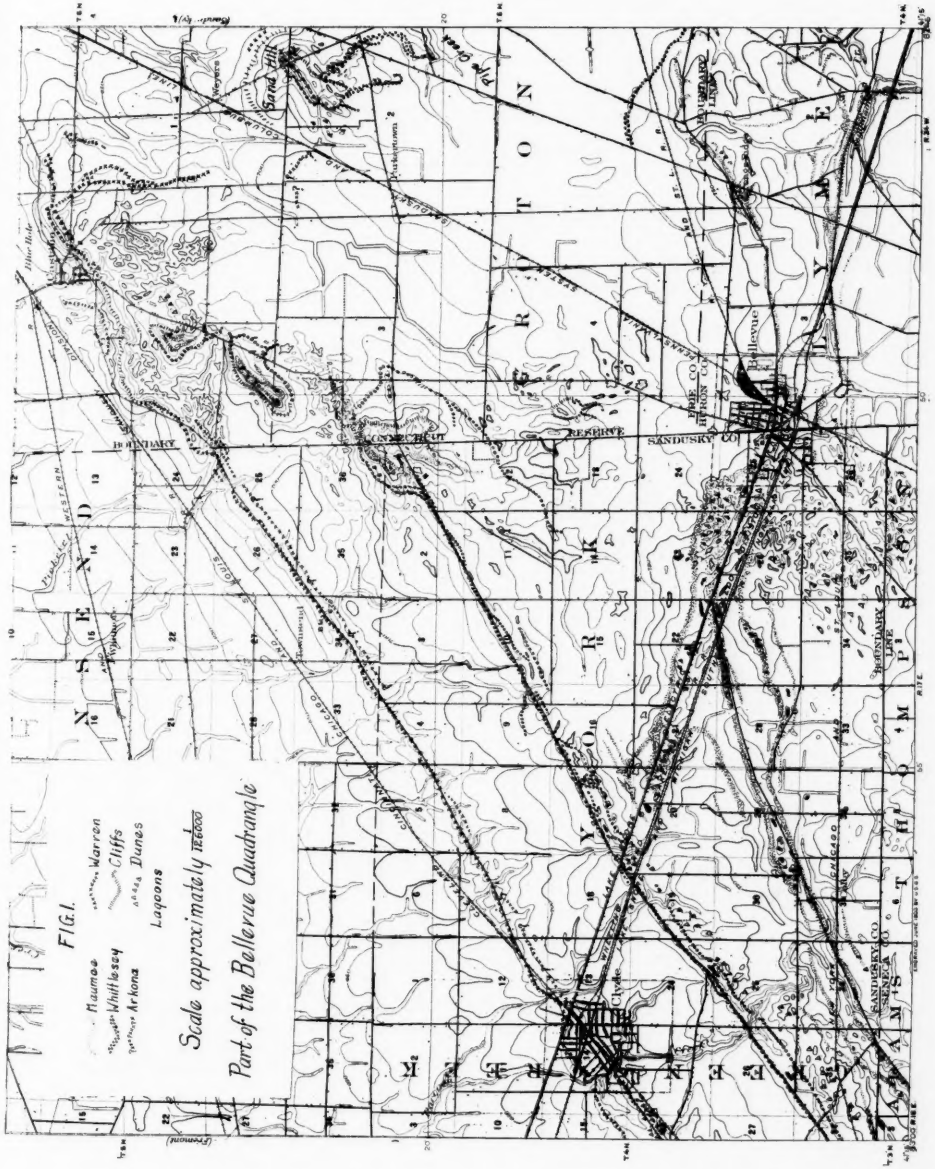
Sand Hill
Pipe Creek
Bellevue
SANDUSKY CO
HURON CO
RESERVE
BOUNDARY
Clyde
SENECA
Warren
Cliffs
Dunes
Lagoons
Maumee
Whittlesey
Arkona
Scale approximately 1:62500
Part of the Bellevue Quadrangle

FIG. I.

disposal; and the farmers find them convenient in disposing of excess water from their fields. The "Blue Hole" near Castalia is the outlet of an underground stream.

Near the south side of the sheet several limited areas rise slightly above the 790-foot contour, and a few dunes reach 800 feet. The more important relief features of the area are due to outcrops of limestone; the shoreline structures and dunes are of minor importance; however, the altitude of some of the hills has been increased 25 feet by dunes blown up from the fringing beaches. The series of hills have a general northeast-southwest direction in alignment with the axis of the Cincinnati anticline which here, as elsewhere in the state, is frequently a drainage divide.

Résumé of lake history. Many workers in geology have contributed to our present knowledge of the pro-glacial lakes. In the Erie basin, which alone is concerned in the present paper, the most recent and critical work is that of Mr. F. B. Taylor and Mr. Frank Leverett. My indebtedness to these gentlemen can not, in all cases, be specifically cited, because in conversation and by correspondence they have given me the benefit of findings as yet unpublished.

It was formerly thought that the recessional movement of the ice-front, during the Wisconsin stage, was interrupted only by halts which are indicated today by the morainic loops about the lake basins. Later it was established that slight oscillations of the ice-margin varied the regressive movement. At least one such readvance was registered on the Thumb of Michigan[6] (the peninsula between Saginaw Bay and Lake Huron); theoretically there must have been two other advances of the ice in this area, though the evidence has not been published.

In reference to the history of several of the pro-glacial lakes of the Erie-Huron Basin, the Thumb of Michigan was a critical area, because, flowing westward across it, lay the outlet channels of these lakes; a readvance of the glacier might cover a given channel, and bury part of the correlating beach beneath outwash deposits; Taylor reports this condition.[7]

[6] F. B. Taylor, "Relations of Lake Whittlesey to the Arkona Beaches," *Mich. Acad. of Science*, report for 1905, p. 34.

[7] *Ibid.*, p. 34.

In the table given below, the lake stages are named in chronological order; but their shorelines do not have a corresponding altitudinal sequence, for the reason that a readvance of the glacier covered the overflow channel last in use, and forced the water to seek a higher outlet, the lake becoming deeper and submerging the shoreline formed when the buried overflow channel was in use. The drowned beach would be altered: if not covered by a great depth of water, the waves and currents would make it "faint and fragmentary;"[8] in any event, the beach would be made "stiffer and more firm than ordinary beach soil . . . . by the infiltration of clay."[9]

LAKE STAGES IN CHRONOLOGICAL ORDER	LOCATION OF OUTLET	ALTITUDE OF SHORELINE IN NORTHERN OHIO
		feet
Highest Maumee, "first" beach	Fort Wayne, Ind.	790±
Lower Maumee, "third" beach (submerged)[10]	Presumably across the Thumb of Michigan	760
Upper Maumee "second" beach	Fort Wayne, Ind.; Imlay, Mich.	780
Arkona (submerged)[11]	Grand River, Michigan	700±
Whittlesey[12]	Ubley, Mich.	735
Wayne (submerged)[13]	Near Syracuse, N. Y.	660
Warren[14]	Grand River, Mich.	680
Grassmere[15]	Near Syracuse, N. Y.	640
Elkton[16]	Near Syracuse, N. Y.	620

[8] *Ibid.*, p. 33.

[9] *Ibid.*, p. 33.

[10] Mr. Leverett first called my attention to this interpretation of the "third" Maumee beach.

[11] Mr. Taylor first called attention to the Arkona as a submerged beach, and showed its time relation to the Whittlesey lake; *loc. cit.*

[12] F. B. Taylor, *Bull. Geol. Soc. America*, vol. VIII, p. 39, proposed this name.

[13] This was formerly called the Lower Warren beach. Mr. Taylor finds it to be older than Lake Warren, by which it was submerged; his interpretation of this episode in pro-glacial lake history will appear shortly in *Monograph No.*—, "The Pleistocene Deposits and Glacial Lakes of Indiana and Michigan," by Leverett and Taylor, U. S. Geol. Survey, part II, chapter XVIII.

[14] The present restriction in the use of the term Warren was proposed by Taylor, *Bull. Geol. Soc. America*, vol. VIII, pp. 56–57, 1897.

[15] This designation was proposed by Mr. A. C. Lane, *Ann. Rept. Geol. Surv. of Michigan*, 1907, p. 131.

[16] Also proposed by Mr. Lane, *ibid.*, p. 132.

The shorelines of only three of these lake stages have been given detailed study on the Bellevue quadrangle. When the field work herein described was undertaken, about four years ago, the writer was not acquainted with any beaches, in northern Ohio, below the Warren; these lower beaches are nowhere suggested by the contours of the Bellevue sheet; in recent summers, however, he has found evidence of these lower beaches on sheets farther west, and he anticipates mapping them later on this quadrangle. There remains also some further work to be done on the Arkona, the significance of which was not fully appreciated in the season of 1909.

Lake Maumee Shorelines

The Upper Maumee shoreline. Commencing on the eastern side of the sheet, the Upper Maumee beach is found along the first north-south highway near the southeast corner. Megginson Creek, the course of which has been influenced by the direction of the beach, cuts through this shore ridge just south of its turn to the west. Within the next mile and a half westward there are some interesting irregularities in this shoreline, in consequence of the influence of west winds. The details can be better understood by starting at a point directly south of Bellevue, where the highway turns northward along the shore of a small pond in section 3 of Lyme Tp. Here the beach has a mild development, but as we follow it to the east by the road, the ridge swinging back and forth across the highway, it grows stouter, and after crossing the Lake Shore Railway the beach shows a strong development. A cusp extends northward about a quarter of a mile along the highway to Strongs Ridge. The road eastward from this cusp follows the crest of the beach for a little more than a mile to a point where the ridge bears north from the highway; a short distance east, the ridge swings back across the road and proceeds southward as already described.

Returning to the cusp on the Strongs Ridge road, we find a spit which grew eastward, developing a northward trend for a short distance and later veering to the south in accord with the depth of the water. About half of a mile east of the western end of this spit, and south of it, a barrier commenced to form and grew eastward for nearly a mile, where both the spit and the

barrier are tied to an area of gravel and sand which bears a cusp-like relationship to the original shoreline. Extending eastward from this cusp-like protuberance is another spit about one-half mile long. A further detail is seen in a ridge of sand, which parallels the two spits just described, and is attached at its eastern end, but I was unable to find that it has any connection with the shoreline proper at its western end; this ridge may have originated as an off-shore barrier and, as the upper level receded, the deposition work of along-shore currents tied it at only one end.

Returning to the meridian of Bellevue, we see on the map isolated gravel patches south and west of the village, as well as an extensive area of dune sand to the southwest. Apparently nearly all of the southern end of the quadrangle, west of Bellevue, was under water during the early part of this Maumee stage. I have been unable, however, to find sufficient sand or gravel in the ridge form to warrant mapping the beach south of the ridge segments indicated. The extension of wind-drifted sand so far south, particularly when we assume that the prevailing wind came more directly from the west, is the reason for hypothecating a former greater extension of Maumee waters in this locality.

For the first mile and a half west of Bellevue, the area included between the Lake Shore Electric, and the Wheeling and Lake Erie Railways, is so continuously covered by sand and gravel that any mapping of the Upper Maumee level must be largely guess work. One can only say that the shoreline crossed this area, and that in post-glacial time there has been so much shifting of sand that the beach itself is obliterated.

Near the point where the Lake Erie and Wheeling Company has a spur, north of its track, leading to a gravel pit, the Upper Maumee beach becomes sufficiently distinct for study. Westward from this point it continues as a ridge, four to ten rods in width, consisting largely of gravel but on its surface becoming progressively more sandy. The several mounds which just reach the 800-foot contour line indicate dunes along this beach ridge. Paralleling this ridge and about a quarter of a mile south is a slighter beach marking an earlier temporary position of the shoreline; how much this differs in altitude, if at all, from the former can not be established, because of wind deposits; it may be the

original position of the shoreline, later isolated by a barrier becoming a beach. The two ridges coalesce one-half mile west of the next north-south highway, and for the next mile and a half the Upper Maumee level is marked by a strongly developed beach. Just west of Colby Station on the Nickle Plate Railroad is found a ridge about three-quarters of a mile long, apparently correlating with the higher ridge above mentioned. The Upper Maumee level proper is indicated by the highway which extends to the southwest, and leaves the sheet about one-half mile east of the western border. Several sand dunes are found in the last mile of this beach.

Islands. The arch of limestone which accounts for Kelley's, Johnson's, and other islands in Lake Erie, made several islands in the pro-glacial lakes. Only the southernmost of the three islands shown on the map, near the Bellevue-Castalia highway, figured in the Upper Maumee stage. This island was very small and may have consisted chiefly of a shoal area. Along only its northwest side is there a beach ridge; the north end of this ridge has a back slope 12 feet in maximum height; the continuity of the ridge and the absence of sand protuberances on its leeward side appear to preclude interpreting it as a wind deposit, although the surface shows sand fine in texture. The general sandy condition of the island's top may be interpreted as wave work of the Upper Maumee; but the same surface condition could be due to later wind-drifting of sand.

The Lower Maumee shoreline. Near the eastern side of the Bellevue sheet, the shoreline of the Lower Maumee level consists of disconnected ridges of sand and gravel. The poor initial development of the shoreline here is due to the fact that limestone, outcropping in the vicinity of Strongs Ridge, acted as a protection against wave-work, and also as a source of abundant sand which formed a spit extending northeastward for over a mile. Near the eastern end of this spit there are two hooks which were later isolated by the spit growing farther into the bay. Leeward of this spit was quieter water, hence a mild beach. This irregular spit owes its location to the shallow water caused by the extension of the limestone outcrop. Furthermore, this spit, even in the absence of shallow water, is normal, as it represents the tendency of the shoreline to straighten itself into the Huron River embayment.

The highway from Strongs Ridge to Bellevue follows the Lower Maumee beach. In the vicinity of Bellevue the shoreline bears southward; the Bellevue cemetery occupies a locally broadened portion of the beach. Its location immediately west of this is somewhat problematical, owing to street grading and building operations. Within half a mile west of the village the Lower Maumee shoreline bears northward, and becomes much broader than elsewhere on the quadrangle. The last position of this lake stage, in this vicinity, may be quite definitely mapped; earlier positions of the beach ridge farther south are indicated by gravel pits operated at present by the Wheeling and Lake Erie Railroad, about a mile west of the Bellevue Cement Company's plant. At this gravel pit the upper 4 to 5 feet consists of wind-drifted sand, beneath which is found some very coarse wave-made gravel. In an area nearly a mile square here the surface material is all wind-deposited.

Proceeding west, the beach of the Lower Maumee level parallels a highway that turns diagonally south and west from the road followed by the Lake Shore Electric. From this point to the southwest corner of the sheet the ridges of the two Maumee levels are approximately parallel. At a point about a half mile northeast of Colby they have been united by wind deposits. For nearly two miles west of this, the lower beach lies a little farther away from the higher ridge, but near the edge of the sheet the two are less than 40 rods apart. In this corner of the quadrangle I have mapped what appears to be a low off-shore barrier, the material of which is prevailingly fine; locally its surface is somewhat irregular because of dune deposits; the barrier characteristic is the continuity of the broad swell of sand.

From the point where the Lower Maumee ridge turns to the southwest from the Lake Shore Electric, there developed to the west one of the most interesting spit formations I have noted anywhere in these studies. From its point of origin in section 22 of York Tp. this spit extends westward over two and one-half miles. The map (Fig. 2) attempts to show as much detail as is possible after eliminating the work of wind deposits; I have allowed only gravel and ridged sand to define definitely this structure. It is observed at once by those who are familiar with the shoreline of Lake Erie, that a striking similarity exists between this spit (Fig. 2) and the Cedar Point spit (Fig. 3). Both have the

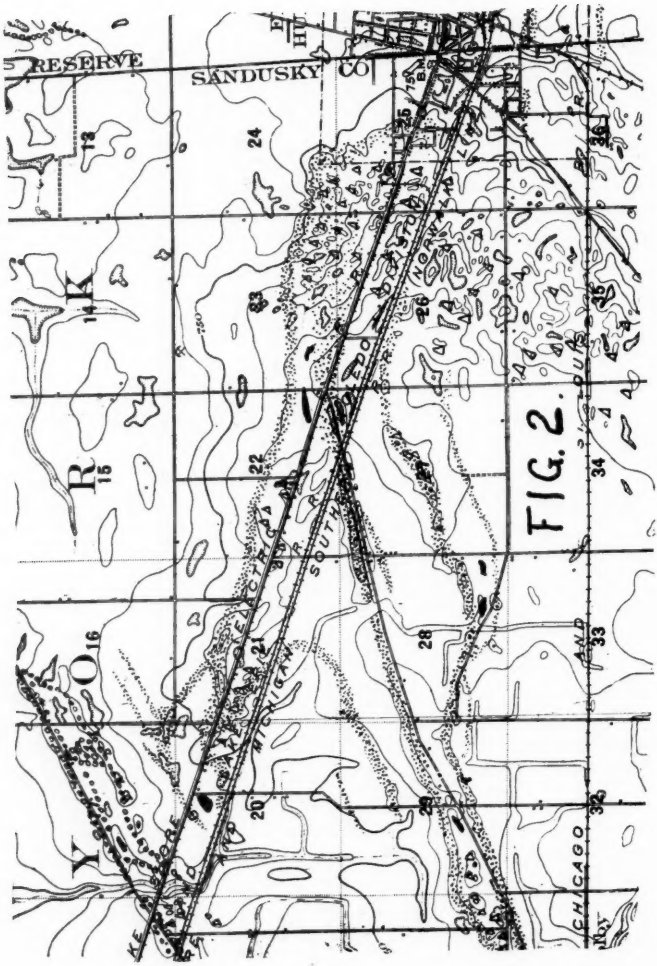

FIG. 2.

same orientation, and are identical in some other details, such as a secondary spit on the inner side, and another on the north shore side; extending eastward from this latter detail of the Bellevue spit, I have mapped three slender ridges of fine sand subaqueous in origin; similar subaqueous ridges are forming eastward from the Cedar Point spit. The secondary development on the south side of the Bellevue spit appears to have grown shoreward till it united with an off-shore barrier in section 21 of York Tp.;

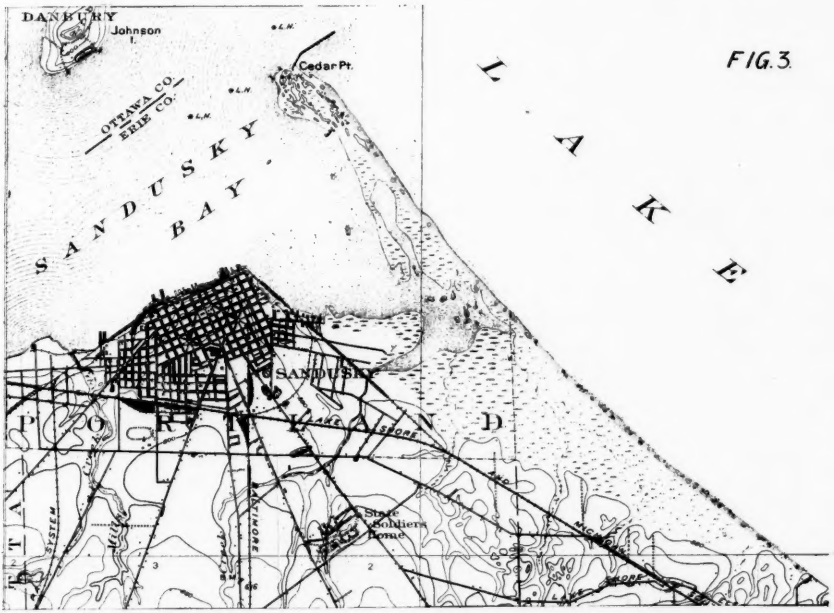

FIG. 3.

an analogous formation appears to be under way at present in Sandusky Bay. The extensive areas of black muck soil in the southeastern part of section 21 and in adjacent parts of other sections of York Tp. indicate that for some time this off-shore barrier and the spit with which it had been united marked the shoreline itself.

When compared with other sheets in Ohio, the Bellevue quadrangle shows the Lower Maumee shoreline in a remarkably well

preserved condition. This must be accounted for largely by assuming a stronger initial form due to an ample supply of detritus for beach-building. However, the characteristic features of a submerged beach are easily detected.

Islands. During the Lower Maumee level, the northernmost of the three islands southwest of Castalia was the smallest in area; its northern shore was cut into a cliff; a beach of gravel and sand forms the remainder of its shoreline; two spits, each about 60 rods long, trend southeastward from the south side of the island.

The middle island does not show any definite cliff. Active wave work, however, is indicated by an abundance of detritus, derived probably from the limestone which was planed to the level of effective wave erosion, and covered. The whole surface is now sandy; in places the sand is in mounds. From near the south end a ridge of sand extends about 70 rods to the northeast, growing finer in texture toward the terminus.

At the close of the Lower Maumee stage the southernmost of these islands had an area of approximately one-half square mile. Steep rock slopes form two-thirds of the island's shoreline. A ridge one mile long extends southward from the middle of the west side; throughout the first half-mile the ridge consists of coarse gravel; it becomes finer in texture southward.

Lake Whittlesey

In the eastern part of the Bellevue sheet the Whittlesey shoreline is not continuous nor are the beach segments well developed, a condition due to the very gradual deepening of the water, and to the windward location of a headland. Throughout the first one and one-half miles the ridge is easily traced; thence for nearly five miles I was unable to give it a definite mapping, though a broad stretch of sandy soil is evidence of wave work. Just east of the Sandusky County line an area of limestone formed an island; on its northern and eastern sides a cliff was cut; elsewhere about the island gravels accumulated; from its southern end a strong spit grew southward nearly one-half mile, terminating in a hook to the west; another slighter spit, a short distance west of this, also developed southward.

At a point about one and one-quarter miles west of this lime-

stone island, commencing in section 14 of York Tp., the beach ridge proper of the Whittlesey level is again found; a school house on the north side of the highway stands near the beginning of this beach. For nearly three miles directly northeast, a ridge of sandy clay marks the work of Whittlesey waves; thence the shoreline turns to the northwest, and becomes quite irregular because of limestone islands, a condition that makes mapping of the shoreline rather problematical. I have indicated some isolated patches of what appear to be wave-worked materials, extending eastward from a cliff phase of limestone. After crossing the Sandusky County line again this beach bears southward for approximately one mile, thence southwest for nine miles, being traversed by a highway continuously to the western border of the quadrangle. As indicated on the map, there are several segments or ridges varying in length, south of the main ridge, which mark earlier, but more temporary positions of the Whittlesey shoreline. Within about a mile of the Lake Shore Electric Railway the ridges become more complex both genetically and by later drifting of sand. South of the Lake Shore and Michigan Central Railroad an inner ridge has been mapped which is continuous, except where cut by streams, to the edge of the sheet.

Islands. An island northeast of Parkertown is locally known as Sand Hill; it was about one mile long, and did not stand very far above the Whittlesey level. The limestone of which it is composed furnished the waves a supply of material for erosion and transportation; cliffs border the northern and northeastern sides of the island. Along its west side are beach deposits, the finer surface parts of which have been drifted inland by the wind; the topographic map appears to indicate several of these dunes, the axes of which, however, are erroneously given a northeast-southwest trend; their direction is more nearly east-west. From the southwestern part of this island a short spit was built into the deeper water. About 40 rods east of this, a strongly developed spit, composed entirely of limestone gravel which becomes finer in texture toward the terminus, extends southward for over one-half mile; this spit has a recurved termination which is very typical in all its measurements; Fig. 4 gives a longitudinal profile and the ground plan of this hook-termination; the direction of the curve shows clearly the influence of deeper water south of the island, carrying the predominating waves to the east.

Joined to the eastern side of this island is another spit of prevailingly coarse limestone material, about one and one-half miles long. Throughout the first three-quarters of a mile, this ridge shows the influence of currents from the north; as the spit neared the axis of the depression now drained by Pipe Creek, the water being deeper gave the waves impelled by the winds from the east a fuller sweep, which tended to turn the spit westward; near the angle, I have mapped three distinct ridges indicating a succession of new spits starting from the angle. The spit continued westward for about one-quarter mile; at that point

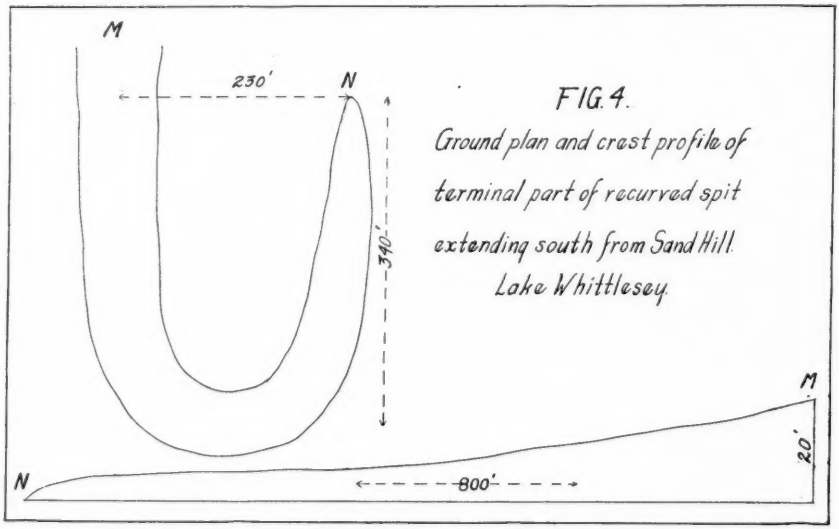

FIG. 4.
Ground plan and crest profile of terminal part of recurved spit extending south from Sand Hill. Lake Whittlesey.

the influence of winds from the west caused it to take a more southerly course. The spit ends a few rods south of the highway; its last half-mile is very much finer in texture than the part developed earlier.

The highway from Castalia to Bellevue crosses two other islands of the Whittlesey stage. The southern of these, on its eastern side, has a well developed beach ridge in which limestone cobble and gravel prevail; on the western side is a cliff with scant gravel and sand at its base. The northern of these two islands is characterized on its west and northwest sides by a beach ridge; at

its southern end, by two spits bearing to the east, both of which are crossed by the above mentioned highway; north of these spits for a distance of about one-quarter mile the shoreline is not distinctly recognizable; a cliff marks the remainder of the island's periphery.

Lake Arkona

The mapping of the Arkona on this sheet is not final; it is known to be incomplete, and there is uncertainty as to some of the deposits interpreted as Arkona.

A submerged beach loses some of its sharpness even when initially strong. The ridge suffers from the work of waves and currents unless covered by a considerable depth of water; in case the transition to the higher stage was effected slowly, there was greater modification of the shoreline. However, the local discontinuance of a beach does not always mean modification; a beach may never have been formed in that place. Along the lakes of today, there are stretches where no shoreline features are developing.

West of Sand Hill there are two low segments of sandy beach slightly above the 700-foot contour. Near the Castalia-Clyde highway, and parallel to the Warren shoreline, are many strips of beach, in places above the 690-foot contour and elsewhere a little below that altitude according to the topographic sketching, which probably represent the Arkona. Another segment is mapped southwest of Clyde; wind deposits in this locality have rendered the mapping quite indefinite.

Lake Warren

The Warren level, throughout the first mile commencing on the eastern side of the Bellevue sheet, is indicated by a cliff skirting Sand Hill. Lying off-shore, near the margin of the quadrangle and continuous with a ridge on the Sandusky sheet, is a low swell of sand, a barrier beach. The cliff slope in the limestone disappears near the Pennsylvania Railroad, west of which is an interval of nearly a mile in which I am unable to find any trace of a shoreline. Eight-tenths of a mile directly west of Weyers is a sandy area which blends northward into a well developed shore ridge, increasing in height toward Castalia. The

outcropping limestone about Castalia furnished an abundant supply of detritus which was drifted alongshore to the south; the terminal part of this ridge bore a spit-relationship to the bay-like expansion of shallow water west of Sand Hill. As indicated on the map, this shore ridge is composite for one-half mile; near the southern junction of the two ridges the Pennsylvania Railroad, several years ago, operated a gravel pit.

Along the east-west highway, directly east of the point where the above mentioned shore ridge commences to bear to the west, a small outlier of limestone formed either an island or an area of very shallow water, southward from which a spit developed; gravel and sand now mark the island or shoal area.

From the angle in the shoreline, just east of Castalia, a spit of large proportions was built eastward one-half mile; its boundaries are somewhat irregular now because of wind deposits. The rather steep limestone slope from this angle westward for approximately one mile bears near its top a ridge of sand and gravel which marks the Warren stage; a period of active wave erosion was followed here by one of beach construction. This ridge extends to the southwest as far as the highway which leads from Castalia to Bellevue. After crossing this highway, the shoreline becomes a cliff in the limestone, and so continues to the more southerly turn of the Clyde highway; the terrace is sandy. In the vicinity of Castalia wind-drifted sand fringes the inland side of the beach.

The Clyde highway follows the Warren beach to that village. Fine gravel and sand prevail; in places the sand has been drifted into mounds. The water side of the beach has a gentle slope; occasionally a steeper slope marks a locality of more active wave erosion. The back slope is regularly short and often steep; its initial curve has been modified by weathering and by wind deposits; the latter agent has operated particularly in the vicinity of Clyde.